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SUBSTANTIATION OF DESIGN PARAMETERS OF VIBRATORY MIXERS FOR FLOUR COMPONENTS

ОБГРУНТУВАННЯ КОНСТРУКТИВНИХ ПАРАМЕТРІВ ВІБРОЗМІШУВАЧІВ ДЛЯ БОРОШНЯНИХ КОМПОНЕНТІВ

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Abstract. *Concern for Ukraine's food security requires maintaining an appropriate level of food self-sufficiency, which implies the use of state support for domestic food producers and the use of import control measures to protect domestic producers from foreign competition. However, society needs healthy, safe and reasonably priced food, and its quality is of particular relevance.*

Therefore, to determine the key parameters of the mixer, a flour bakery mix with a high protein content was selected. In this regard, an attempt was made to obtain these mixtures using the original continuous vibrating mixer. During the study of the feasibility of preparing a flour bakery mixture with a high protein content in a vibratory mixer, the rate of its vibration transportation was experimentally determined. In determining the efficiency of mixing processes, in addition to the speed of vibration transportation of the flour bakery mixture, the power consumption of the equipment is of great importance. Therefore, studies were also conducted to determine the mutual influence of the mixer's technological parameters on power consumption.

An analysis of the study results to determine the influence of key parameters on the vibration transportation speed of the flour bakery mixture υ showed that it increases with an increase in the oscillation frequency of the working body f and the amplitude of oscillations A. Also, the study found that the higher the amplitude and frequency of oscillations, the greater the power consumption of the vibratory mixer.

Key words: *mixing, flour components, protein, vibration, vibration transportation speed, vibration amplitude, vibratory mixer.*

Introduction.

Adequate safe and balanced nutrition is an important factor for sustaining life and promoting health. Particular attention is paid to ensuring the proper quality and safety of food products sold on the domestic market and their affordability for the population of Ukraine.

Protein occupies a special place among all organic substances. Protein is an essential macronutrient that is involved in the functioning of the entire body. It is found in muscles, bones, hair, skin, and almost all parts of the body and tissues. To remove it from the diet is to harm yourself. Based on this, flour components with a high protein content were selected to conduct research to determine the parameters of the vibratory mixer. For the production of dry flour mixtures, it is necessary to ensure an even distribution of the components [3,4,5,22]. Vibratory mixers are used for this purpose due to their simple design and high mixing efficiency. The study of the operation of continuous vibratory mixers is an urgent scientific task for the food industry. The aim of this work is to determine the parameters of a vibratory mixer to obtain a flour mixture with a high protein content of a given quality [6,7,8,23,24].

Research methodology.

The object of study is an original continuous vibration mixer.

The subject of the study is the factors influencing the process of mixing a flour bakery mixture; the dependence of the influence of the frequency of oscillations of the working body and the amplitude of oscillations; determination of the speed of vibration transportation of the flour bakery mixture.

The analysis of the raw material market showed the effectiveness of using for experimental studies the following recipe components with a protein content of at least 22 g per 100 g of product: almond flour (22 g of protein per 100 g of product), whey isolate (95 g of protein per 100 g of product), soy protein isolate (91 g of protein per 100 g of product), dry wheat gluten (76 g of protein per 100 g of product). To calculate the nutritional value, we used the methodology of conversion factors for the energy value of the main food substances of food products, according to which 1 g of protein contains 4 kcal or 17 kJ [14,18,19]. Thus, the recipe for a flour bakery mixture with a high protein content was modeled, which is presented in Table 1.

When studying the feasibility of the selected flour components with a high protein content, the speed of their vibration transportation through the working body of a vibratory mixer was experimentally determined. It has a significant effect on the performance of the mixer, its geometric parameters, and depends on the angle β, amplitude A, and frequency f of vibration, as well as on the height of the vibrating boiling layer (VBL) and the presence of perforations on the working body of the vibratory mixer.

Table 1 – Recipe for flour baking mix with high protein content

Name of raw materials	Raw material consumption, kg
High-grade wheat flour	82,5
Almond flour	4,5
Food salt	1,3
White crystalline sugar	1,8
Whey isolate	4,5
Soy protein isolate	4,5
Dry wheat gluten	0,9
Total:	100,0

The determination of the speed of vibrotransportation of the flour bakery mixture through the working body of the mixer was carried out according to the following method:

1. The average length of the path of movement of the components of the flour bakery mixture along the mixer's working body was determined by the following formula:

$$l_{av} = \frac{2\pi(D_{out}+D_{inn})}{4\cos\gamma} \quad (1)$$

where *lav* – average length of the surface along which the mixture moved, m; *Dout* – outer diameter of the working body, m; *Dinn* – inner diameter of the working body, m; γ – angle of inclination of the screw working body.

2. An indicator particle (a tinted grain of edible salt) was added to the flow of the flour bakery mixture and the time of its passage through the working body of the vibratory mixer was measured.

3. The speed of vibration transportation of the flour bakery mixture through the working body of the apparatus was determined by the formula:

$$v_{av} = \frac{l_{av}}{t_{par}} \quad (2)$$

where v_{av} –speed of vibration transportation of the flour baking mixture through the working body of the apparatus, m/s; t_{par} – time of passage of the indicator particle through the working body of the vibratory mixer, s [6,8].

Research results.

The following parameters were used in the study to determine the speed of vibration transportation of a flour bakery mixture through the working body of a vibratory mixer: vibration angle (β = 20, 35, and 45°), amplitude (A = 0,0015, 0,0030, and 0,0040 m), unbalance oscillation frequency (f = 14,36, 19, 23, 26, and 29,36 Hz), height of the vibro-boiling layer (VCS = 0,01, 0,02, and 0,03 m), perforation (d = 0,003, 0,005 m; without perforation).

The results of studies to determine the speed of vibration transportation of the flour bakery mixture through the mixer's working body are shown in Figures 1–4 and in the form of analytical equations [1,2,9].

Figure 1 shows a group of lines reflecting the effect of the amplitude A and frequency f of oscillations on the speed of vibration transportation of the flour bakery mixture through the working body of the vibratory mixer (vibration angle β = 35°, height of the VCS 0,01 m, no perforation).

Figure 1 shows that the highest values of the velocity of vibration transport of the flour bakery mixture along the mixer's working body are observed at A = 0,0030 m, and the lowest at A = 0,0015 m. Accordingly, the greater the amplitude A and the vibration frequency f, the higher the velocity of vibration transport of the flour bakery mixture υ. The amplitude is responsible for lifting the material to a certain height from the plane, thereby contributing to better movement of the mixture along the working body of the machine. Therefore, to intensify the process of mixing flour bakery mix and increase the productivity of the machine, it is necessary to increase these parameters. The approximating equations of the obtained lines are as follows:

$$v_1 = 0{,}003f - 0{,}042 \; (A = 0{,}0015 \; m), \quad (3)$$

$$v_2 = 0{,}004f - 0{,}018 \; (A = 0{,}0030 \; m), \quad (4)$$

$$v_3 = 0{,}005f - 0{,}035 \; (A = 0{,}0040 \; m) \quad (5)$$

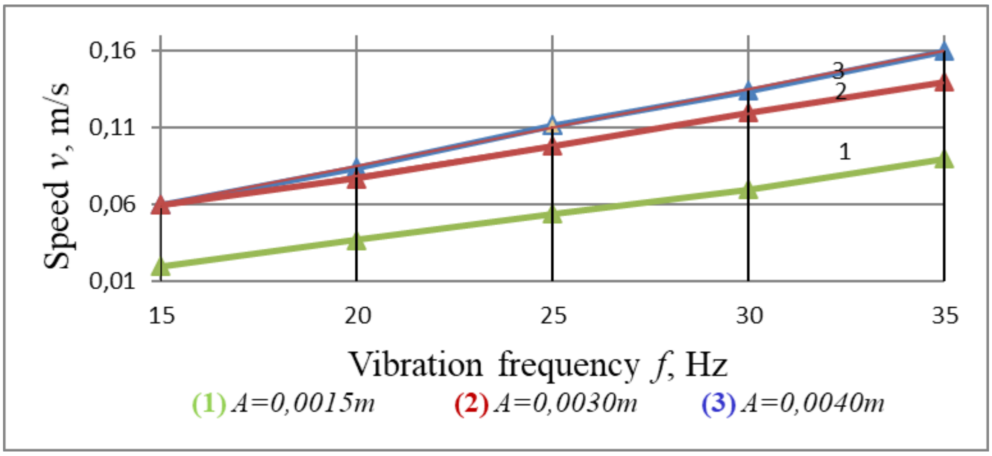

Figure 1 – Graphical dependence of the speed of movement of the flour baking mixture on the working body on the amplitude (A) and vibration frequency (f)

Figure 2 shows a group of lines reflecting the effect of the height of the VCS and the vibration frequency f on the speed (vibration angle β = 35°, vibration amplitude A = 0,0040 m, no perforation).

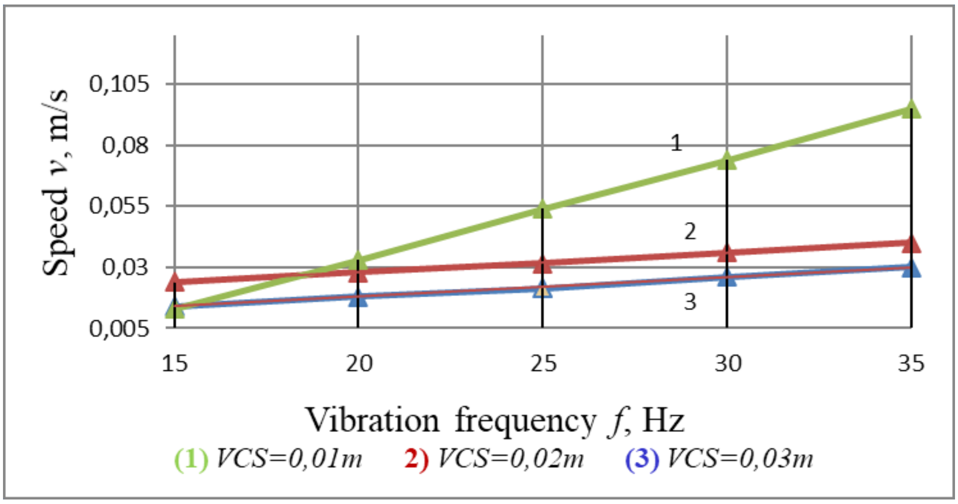

Figure 2 – Graphical dependence of the speed of movement of the flour baking mixture on the working body on the height of the VCS and the vibration frequency (f)

Figure 2 shows that the highest velocity of vibration transportation of the flour bakery mixture is observed at a VCS of 0,01 m, and the lowest at 0,03 m. It can be concluded that the higher the vibration frequency f and the lower the VCS, the higher the vibration transportation speed of the studied mixture. This is explained by the following: under the influence of vibration, the particles of the flour baking mixture layer begin to move upward. At this point, a vacuum is formed under the layer, due to which air is sucked through the hole [20,21]. The mix's VCS captures the air from below and forces it upward, acting as a «pump» that transports air through itself. Air penetrating under the material layer through the perforations «closes» the holes and impairs the flow of the dispersed phase through them. Accordingly, the higher the material's VCS, the better the mixture flows through the perforations and the lower the rate of vibration transportation of the flour baking mixture. The approximating equations of the constructed lines are as follows:

$$v_1 = 0{,}003f - 0{,}045\ (h = 0{,}01\ m), \quad (6)$$

$$v_2 = 0{,}002f - 0{,}025\ (h = 0{,}02\ m), \quad (7)$$

$$v_3 = 0{,}001f - 0{,}001\ (h = 0{,}03\ m), \quad (8)$$

Figure 3 shows a group of lines reflecting the effect of the vibration angle β and frequency f on the velocity (vibration amplitude A = 0,0040 m, height of the VCS = 0,01m, no perforation).

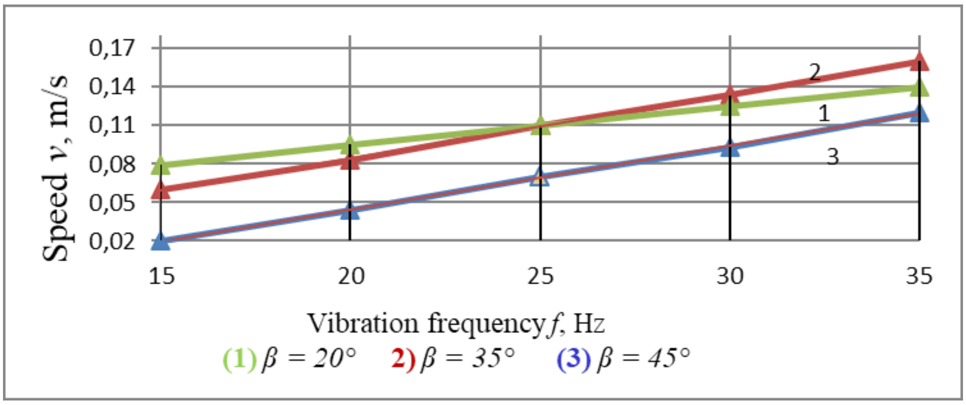

Figure 3 – Graphical dependence of the speed of movement of the flour baking mixture on the working body on the angle (β) and vibration frequency (f)

Figure 3 shows that with increasing vibration angle, the vibration transportation speed decreases. The maximum value is achieved at a vibration angle of β = 35°, since at this vibration angle the directional rotary-screw movement of the mixture is more intense. Therefore, to increase the productivity of the vibratory mixer, it is more expedient to set this value of the vibration angle. At a vibration angle of β = 20° and β = 45°, less favorable conditions are created for the movement of the flour bakery mixture. The approximating equations of the lines are as follows:

$$v_1 = 0{,}005f - 0{,}019\ (\beta = 20^{\circ}) \quad (9)$$

$$v_1 = 0{,}005f - 0{,}027\ (\beta = 35^{\circ}) \quad (10)$$

$$v_1 = 0{,}005f - 0{,}056\ (\beta = 45^{\circ}) \quad (11)$$

Figure 4 shows a group of lines reflecting the effect of the diameter of the holes d of the working body and the vibration frequency f on the speed (vibration angle β = 35°, vibration amplitude A = 0,0040 m, height of the VCS 0,01 m) [10-13].

Figure 4 shows that the highest values of the velocity of vibration transportation of the flour bakery mixture are observed at a perforation diameter of d = 0,005 m, and the lowest at its absence. Consequently, the larger the diameter of the perforation of the working body d, the higher the speed of vibration transportation of the flour baking mixture. The increase in the studied parameter occurs due to air suction through the layer [15,16,17].

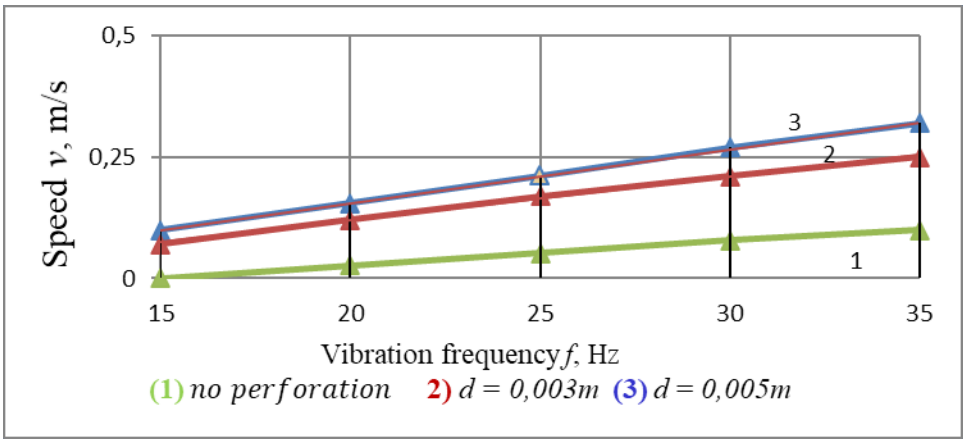

Figure 4 – Graphical dependence of the speed of movement of the flour baking mixture on the working body on the diameter of the perforation of the working body (d) and the vibration frequency (f)

To study the effect of the perforation area of the working body on the speed of vibration transportation of the flour bakery mixture, hole diameters of 0,003 and 0,005 m were taken in order to exclude the effect of changing the height of the layer on the speed of vibration transportation, since at large values of the perforation area, the VCS of the flour bakery mixture on working turns decreased. At the diameter of the holes (e.g., d = 0,0015 m), an increase in the VCS of the flour bakery mixture on the working body of the vibratory mixer was observed, which leads to a decrease in the vibration transportation speed. The approximating equations of the lines are as follows:

$$v_1 = 0{,}005f - 0{,}035 \ (no\ perforation), \quad (12)$$

$$v_2 = 0{,}011f - 0{,}125 \ (8\ hol., d = 0{,}003\ m), \quad (13)$$

$$v_3 = 0{,}015f - 0{,}175 \ (8\ hol., d = 0{,}005\ m) \quad (14)$$

Figure 5 shows the results of a study to determine the mutual influence of the amplitude (A) and oscillation frequency (f) of a 20,0 kg mixer on power consumption. The study also revealed that the moisture content of the flour baking mixture, which can change in the process of acting on the mixture, has a great influence on the power consumption [25,26,27].

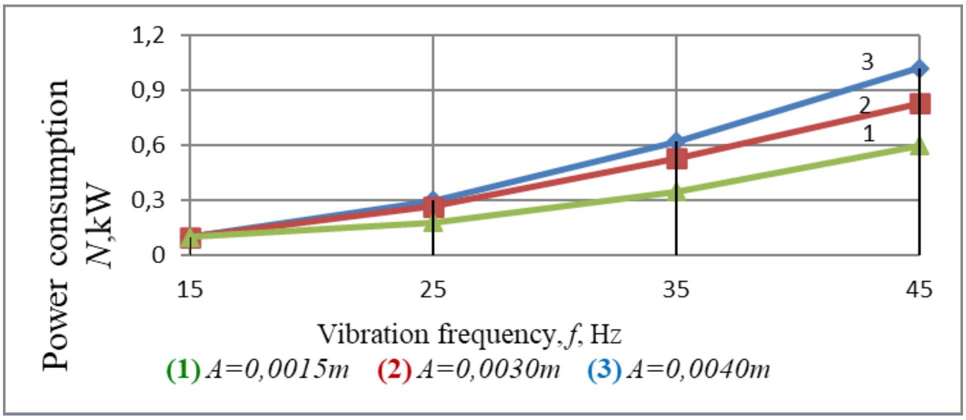

Figure 5 – Dependence of power consumption of a 20,0 kg mixer on vibration amplitude and frequency

Conclusions.

The analysis of the results of the study to determine the influence of parameters on the speed of vibration transportation of the flour bakery mixture υ showed that it increases with an increase in the frequency of oscillations of the working body f and the amplitude of oscillations A, and a slight decrease in its growth in the studied range can be explained by the increasing effect of flour slipping in relation to the vibrating surface in the mode of its detachable movement along the working body. Also, during the studies, an increase in power consumption was observed with an increase in the amplitude and frequency of oscillations. Since the speed of vibration transportation of the flour bakery mixture at a vibration amplitude of A = 0,0040 m is not much different from that at A = 0,0030 m, it is more expedient to use it to reduce the power consumption of the vibratory mixer. As a result of the study, we determined the rational parameters of the vibration mixer when producing flour bakery mixtures: vibration amplitude A = 0,0030 m, vibration angle β = 30°, height of the vibro-boiling layer 0,01 m, perforation diameter of the working body of the apparatus d = 0,005 m.

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Анотація. *Турбота про продовольчу безпеку України потребує підтримки відповідного рівня продовольчого самозабезпечення, яка передбачає використання державної підтримки вітчизняних виробників харчової продукції та використання заходів контролю імпортної продукції з метою захисту власних виробників від іноземної конкуренції. Проте суспільству потрібне корисне, безпечне для здоров'я і досить дешеве продовольство, а його якість набуває особливої актуальності.*

Тому для визначення ключових параметрів роботи змішувача була підібрана борошняна хлібопекарська суміш з високим вмістом білку. Була зроблена спроба отримати ці суміші на оригінальному вібраційному змішувачі безперервної дії. Під час дослідження у віброзмішувачі доцільності приготування борошняної хлібопекарської суміші з високим вмістом білку експериментально визначали швидкість її вібротранспортування. При визначенні ефективності процесів змішування, окрім швидкості вібротранспортування борошняної хлібопекарської суміші, важливе значення має споживана потужність обладнання. Тому також були проведені дослідження з визначення взаємного впливу технологічних параметрів змішувача на споживану потужність.

Аналіз отриманих результатів дослідження із визначення впливу ключових параметрів на швидкість вібротранспортування борошняної хлібопекарської суміші v показав, що вона зростає із збільшенням частоти коливань робочого органу f і амплітуди коливань A. Також в ході досліджень з'ясувалося, що чим вище амплітуда і частота коливань, тим більше значення споживаної потужності віброзмішувача.

Ключові слова: *змішування, борошняні компоненти, білок, вібрація, швидкість вібротранспортування, амплітуда вібрації, вібраційний змішувач.*

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